Detection of an Extrasolar Planet

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The objective of this research is to determine the occurrence frequency and the properties of extrasolar planets.

Information on the number, size, mass, spacing, and composition of the planets in other planetary systems is needed to refine our models of planetary system formation and the processes that gave rise to their present configurations. The recent discoveries provide tantalizing glimpses of the large variety of planetary systems that exist and make it possible to begin an investigation of the role of the giant planets. To obtain information on the statistical properties of the giant inner planets, and to develop the statistical dependencies of these properties, it is necessary to observe many of these objects for a variety of stellar spectral types and stellar compositions, and for a range of semi-major axes.

A small charged coupled device (CCD) photometer dedicated to the detection of extrasolar planets has been developed at Ames Research Center and put into operation at Mt. Hamilton, California. It simultaneously monitors 6000 stars brighter than 13th magnitude in its 49-square-degree field of view. Observations are conducted all night every clear night of the year. A single field is monitored at a cadence of eight images per hour, for a period of about three months. When the data are folded, in order to discover low-amplitude transits, transit amplitudes of 1% are readily detected. This precision is sufficient to find jovian-size planets orbiting solar-like stars, which have signal amplitudes from 1 to 2%, depending on the inflation of the planet atmosphere and the size of the star.

Recent observations made with the Vulcan photometer produced over 100 variable stars, many not previously known. About 50 of these stars are eclipsing binary stars, several with transit amplitudes of only a few percent. Three stars that showed only primary transits were examined with high-precision spectroscopy. Two were found to be nearly identical stars in binary pairs orbiting at double the photometric period, and the third was found to be a high-mass-ratio single-lined binary star.

The November 22, 1999, transit of a planet orbiting HD209458 was observed and the predicted amplitude and immersion times were confirmed. These observations show that the photometer and the data reduction and analysis algorithms now have the necessary precision to find companions with the expected area ratio for jovian-size planets orbiting solar-like stars.

In early November 1999, two groups announced the discovery of a planet orbiting HD209458 in the Pegasus constellation. The symbols in figure 1 show the extinction-corrected, normalized light curve obtained for HD209458 on November 22, 1999. Because this event was the last opportunity to observe the transit, observations were made, even though the star was setting during the transit. Consequently, only the first portion of the transit is seen. The solid line represents the predictions based on the work of Charbonneau et al. and Castellano et al. (1999). Both the limb-crossing time (25 minutes) and the measured amplitude of the transit (1.6%) are in excellent agreement.

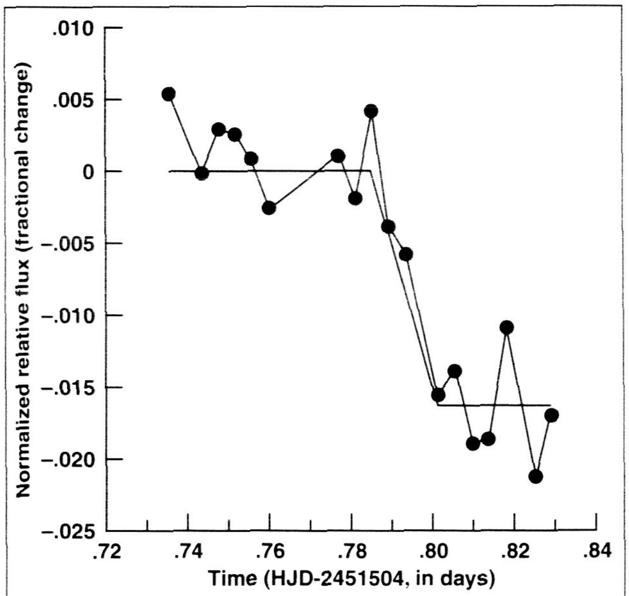

Fig. 1. Comparison of the measured and predicted flux for the November 22, 1999, transit of a planet orbiting HD209458.

Ordinarily, photometry is done as close to the meridian as possible to mitigate the error introduced by scintillation and rapid extinction variations that are associated with high air mass. For this reason, measurements are usually made at an air-mass less than 1.5 and seldom are made at an air mass as large as 2.0. However, to obtain the data on November 22, the measurements were made as the air mass ranged from 1.5 to 4. Figure 2 shows the measured rapid increase in standard deviation (SD) of the fluxes of the seven comparison stars at the time of the measurements. The solid curve shows the expected level of scintillation noise. The agreement between these measurements and the predictions of the scintillation noise demonstrates that the system was operating at a precision limited only by properties of the atmosphere. The observations were terminated at an air mass of 4 because the signal-to-noise ratio had dropped below 2.5 at that point.

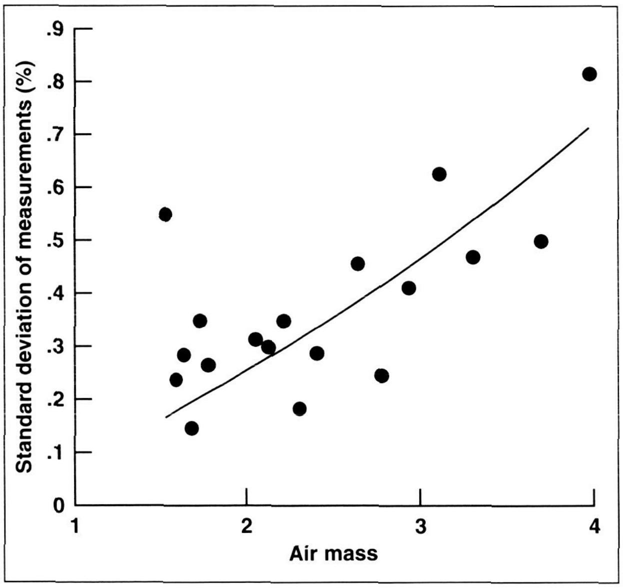

Fig. 2. Comparison of the standard deviation of the fluxes of the comparison stars with the prediction of scintillation noise by Young (1974).

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Planetary Rings

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In addition to the natural curiosity inspired by their unusual appearances, planetary rings present a unique dynamical laboratory for understanding the properties of collisional particle disks that might help us understand the accretion of the planets. Ames maintains the Planetary Data System's Rings Node (http://ringmaster.arc.nasa.gov/), which archives and distributes ring data from NASA's spacecraft missions and from Earth-based observatories. The entire archive of images from the Voyager missions to the giant planets is now available on line, with catalogs to help users find the images they need. All the images of Saturn obtained by the Hubble Space Telescope (HST) during 1995, when the rings were seen edge-on to Earth, are available.

An important theoretical advance was taken in the development of a new theory for how narrow, elliptical rings, with nested elliptical orbits, preserve their shape over long periods of time in the face of the tendency of their inner orbits to precess more rapidly than their outer orbits, causing misalignment and collisional disruption. The major previous theory relied exclusively on ring self-gravity to provide the slight counteracting force needed to prevent this precession, but the mass implied was much smaller than that believed to lie in these rings based on other observations. This year, new physics was added to the equations of motion in the form of pressure tensors in dense particle layers that behave like traffic jams. The new physics, in fact, makes it more difficult for self-gravity to maintain the alignment of the nested orbits, and boosts the needed mass density into much better agreement with observations.

New observational results were also obtained from analysis of extensive HST observations of Saturn's rings, taken over the last three years as the ring opening angle increased as seen from the Earth and the Sun (figure 1). Taken in eight different colors (several not observable from Earth), these new observations show for the first time that the ring brightness varies with phase angle but not with ring opening angle. This finding makes it clear that the reflectivity is caused by multiple scattering within a granular regolith on large ring particles, but not between ring particles. This result led to the